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Inventor: Sines
Serial No. 09/364,256

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PATENT APPLICATION
Navy Case No. 79,955

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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In re application of: E. Sines

Serial No. 09/364,256

Filed: July 30, 1999

Examiner: G. Perez

Group Art Unit: 2834

For: ELECTRICAL POWER
COOLING TECHNIQUE

DECLARATION IN SUPPORT OF AN APPLICATION BY SINES

Associate Commissioner for Patents
Washington, DC 20231

Sir:

I, GREGORY A. COWART, hereby declare that:

1. I am employed as a Branch Head of the Aerospace Electronic Warfare Systems Branch in the Tactical Electronic Warfare Division of the Naval Research Laboratory at Washington, DC.

2. I further declare that I have a Doctor of Philosophy degree in physics granted in 1984 by the Catholic University of America . For the past 17 years I have worked in

the field of electromagnetic devices. I have authored nine papers on the electromagnetics of electronic warfare.

3. I further declare that I have reviewed the patent application entitled ELECTRICAL POWER COOLING TECHNIQUE by Eddie Sines, Serial No. 089/364,256, filed on July 30,1999; Japanese Patent No. Hei 1-105840, entitled SALIENT-POLE ROTARY FIELD SYNCHRONOUS MACHINE, by Kanai Hitishi, filed April 27, 1989; Japanese Patent No.Hei 8-3167133, entitled SALIENT POLE TYPE ROTOR, by Shimaya, Hiromoto, filed November 18, 1997; U.S. Patent No. 3,123,747; MAGNETIZABLE CORE; by J.P. Glass, issued March 3, 1964; U.S. Patent No. 3,671,787, entitled LAMINATED DYNAMOELECTRIC MACHINE HAVING NONMAGNETIC LAMINA FOR STRUCTURAL SUPPORT; by C.C. Herron, issued June 20, 1972; U.S. Patent No. 5,091,666, entitled STATOR COOLING SYSTEM FOR ELECTRICAL MACHINERY, by E. Jarczynski, issues February 25, 1992; U.S. Patent 5,949,170, entitled METHOD AND APPARATUS FOR REDUCING VOLTAGE STRESS IN ELECTRIC MOTORS, R.M. Davis, issued September 7, 1999.

4. The object of the *Kanai* patent is to provide a reduced thermal grade in the field windings to make a lightweight, compact salient-pole rotary field synchronous motor. *Kanai* tried to solve the problem of heat by inserting heat dissipation plates into the windings which protruded out of the

windings where forced air is used to cool them. The dissipation plates provide an increased radiation surface to the salient-pole rotor motor windings.

Kanai describes the installation of heat dissipation plates which are in the form of fins that are placed among the conductors to provide paths for heat to conduct to the dissipation plates which protrude out of the field windings. On Page 4 of the English translation of the patent, *Kanai* identifies the material of the dissipation plates as "aluminum", known to be a metal and easily conduct electricity. This differs materially from the Applicant's application in that the claimed device utilizes an insulator to conduct the heat out of the motor and not a metal.

The *Kanai* patent primary means of heat removal is through radiation and forced air. The heat dissipation plates can further be modified with slots to hold the field windings when they become long. *Kanai* fails to clearly understand that adding a metal into the coil windings of the stator motor causes problems due to eddy currents being induced into this metal and their affecting the performance of the stator motor.

Kanai used a metal comprised of aluminum, and this metal is subjected to changing magnetic fields in the stator windings and will produce eddy current losses in the form of heat, which only adds to the heat loss of the stator motor, or at the very least

reduces the effectiveness of the dissipation plates. The Applicants claimed invention uses an insulator with superior thermal conductivity, not a metal and therefore this material does not produce large quantities of eddy currents when directly exposed to or subjected to high density changing magnetic fields. This is a critical and material difference between the prior art and the claimed invention.

Kanai teaches the use of a metal to remove heat from the surface of the coil windings. These dissipation plates are in close proximity to the changing magnetic fields of the motor and therefore will produce eddy current losses in the form of heat and adding to the motor losses. This is not the case in the Applicants claimed device. In addition, the eddy currents will effect the magnetic structure by producing counter magnetic forces which will redirect some of the magnetic lines of force causing increased inductance losses due to stray magnetic fields not being tightly linked to the coils and stator pole. The Applicants claimed invention uses a material known as K1100 that does not have as much effect as a metal (~ 35X's less when compared to aluminum) and therefore would produce less stray magnetic losses in the motor. This is a very important difference when the goal is lighter, smaller motors.

The material utilized by the applicant in the claimed device is very light and can be attached to the windings through simple

adhesive action during the construction of the transformer or motor sealing. The risk of coming apart due to centrifugal force is very small due to the low specific weight of the carbon material, typically 10's of grams per coil.

Both *Kanai* and *Shimaya* suggested a material with high thermal conductivity, but they did not specify or indicate it to be non-magnetic. Instead *Kanai* used aluminum in his stator coil windings. Aluminum is a metal, and it is known to be a good conductor of electricity and therefore subjected to large eddy currents when placed in the presence of a changing magnetic field, as one would find within the motor coil windings, and therefore, would be a poor choice of material to remove heat from the rotor stator coil windings.

As stated above, eddy-current losses, in the form of heat, are ~35X's more for aluminum than the K1100 while exposed to the same magnetic fields. This is because aluminum is a much better conductor of electricity than the high modulus carbon fiber known as K1100. This is a major difference between the Applicants claimed invention for motor/generators and the *Kanai* patent.

The Applicants claimed invention provides a unique thermal interface solution that is superior over *Kanai* and is not technically flawed due to excessive eddy-current losses in the material used to conduct heat and adding to the motor heat load. By using a high modulus carbon fiber, a direct thermal path is

provided from the interior of the motor windings to the outside motor casing, providing a cooling path to the windings directly, free of additional eddy current heat losses. This minimizes the migration of heat into the motor laminations and allows for an increase in current density, reduces total system weight, reduces volume and improves system reliability.

Kanai merely conducts the heat off the outside of the windings unlike the invention claimed by the Applicant where there is a thermal interface that goes directly into the interior of the motor windings and this is another critical difference between the prior art and the claimed invention.

When the Applicants claimed invention is applied to motors, they will run more efficiently because the motor windings will remain cooler due to the improved thermal path to the ambient atmosphere provided by the K1100 material. Now heat can be efficiently dissipated through forced air methods, reducing the system weight for the much needed airborne applications. High modulus carbon fiber known as K1100, conducts heat at ~2.4X better than copper and ~4.8X better than aluminum. The benefits of using the high carbon fiber thermal interface are very important to future motor development and different enough to merit a patent in my opinion, by allowing motor technology to move forward without the technical short falls of metals, while providing superior thermal performance to the interior of the

motor windings

5. In the *Herron* patent, 3,671,787, the inventor teaches the design and fabrication of a motor using standard materials and a non-magnetic lamina said to be aluminum. Column 1, Lines 25-35. *Herron* teaches that these non-magnetic laminas can be stamped and formed by metal stamping techniques and are preferably made from aluminum or brass. Column3, Lines 15-20. These stampings are designed with voids and chambers for transverse cooling air to be forced through them, Column 3, Lines 35-45. Also, note, that in the title of the invention,

Herron places non-magnetic laminas into the design structure to provide mounting points for the permanent magnetics and to provide the necessary working air gaps as well as producing a low reluctance flux path for the motor to operate in. These non- magnetic laminas are also designed to aid in cooling the motor assembly by adding void and chambers, but this is not the primary function. See Column 1, Lines 35-45.

Herron states in Claim 2 that these non-magnetic laminas are used to form cooling fins. The concept of using any metal in this area is technically incorrect due to the changing magnetic fields the non-magnetic laminations said to be aluminum or brass would be subjected to in the motor. Aluminum and brass are both good conductors of electricity and when subjected to changing

magnetic fields they produce eddy currents that react as previously stated. *Herron* also relies on forced air for cooling the internal structure and designs the cooling paths directly into the motor to facilitate the flow of air. The *Herron* motor is simply a complex air-cooled motor due to the air passage ways integrated into the internal mechanical structure of the motor.

The claimed invention of the applicant is not in conflict with the *Herron* patent because the claimed device uses a completely different scientific method of removing heat from the internal structure of an electrical motor. *Herron* describes the cooling fins as non-magnetic laminas, not as "thermally conductive disks" and/or "thermally conductive strips." Reference the Examiner's rejections numbers 2 and 4. At no time has *Herron* taught such disks or strips, *Herron* relies on metal to conduct the heat out of the motor or to the fin tips and then to the ambient air. The applicants claimed device relies on an insulator made from carbon to conduct heat out of the motor to the ambient, this is a major structural difference between the two devices.

The material used in the Applicants claimed invention is carbon and carbon materials conduct ~35 times less electricity than aluminum or brass, thereby producing almost no additional heat load to the motor while being exposed to high density changing magnetic fields, a very important difference. The

Herron patent teaches the removal of heat from small air passages ways which only exasperates and confines the heat problem. The heat in the *Herron* motor must conduct through many layers of material before it can pass into the air. If the air flow is restricted by small passages ways, this only reduces the heat sinks ability of the non-magnetic laminations to remove heat effectively because of the limited surface area contact and low velocity of the air flow. Small air passages and small air flow.

The high modulus carbon thermal interface on the other hand provides multiple, low impedance, parallel thermal paths for the heat to move through and thereby reduces the thermal resistance to a minimum. Heat is conducted into multiple K1100 thermally conductive layers by placing them into direct contact with the hot surface laminations and the windings, shunting heat directly out of the interior of the motor.

Note also, that K1100 conducts heat at ~2.4X better than copper and ~4.8X to ~5.8X better than aluminum or brass. Because multiple laminations of the thermal conductor are applied to the motor in the Applicants claimed invention, they raise the total surface area of the collection surface which also reduces the thermal resistance path to ambient and thereby lowers the internal temperature of the motor so that one can now increase the current density providing a more powerful smaller motor. Voids and air chambers only make the motor larger, further

increasing the heat load due to increase losses in the magnetics material of the larger motor. The *Herron* and the Applicants claimed invention teachings are quite different in the extraction of heat for the internal structures of the motors and therefore a patent should be granted.

6. In the *Davis* patent 5,949,170, Davis teaches the application of capacitive voltage distribution methods in order to reduce the damage to the motor windings due to high speed voltage transients related to the voltage wave forms used to control reluctance motors during switching. *Davis* had discovered determined by experience that shorting occurs in the first few turns of the motor windings due to insulation breakdown from high-speed voltage transients that fatigue the insulation. The heat developed results in insulation break down. Column 2, Line 10.

Davis teaches a method of controlling the windings failure problem in switched reluctance motors systems. Column 2, Lines 32-38. *Davis* further teaches the construction of this internal distributed windings capacitor and how he integrates this into each phase of the reluctance motor windings. The primary goal of *Davis* is to distribute the voltage stress from switching over more windings and to reduce the voltage peaks of the transient voltage spikes in order to protect the windings insulation.

Davis teaches both strips and helically wound configurations to implement these distributed windings capacitors. Column 3, Lines 47-50.

Davis teaches that there is no real need for a particular composition of insulating sheet or material, but the material should be relatively thin with high dielectric strength and good thermal conductivity. Column 7, Lines 20-25. *Davis* recommends the use of an aramid paper, such as NOMEX, as a suitable construction material because it is light weight, very strong heat-resistant synthetic material and comes in sheet form. *Davis* sandwiches this between two layers of windings, at the start of the windings to distribute the voltage stress of the switching waveform. Between this insulating material, *Davis* adds electrical conductors like aluminum, copper, conductive plastics, graphite conductive mats for the purpose of building a capacitive voltage distributor. Column 7, Lines 40-55.

Davis had no intentions, nor did it teach, the use of the capacitive voltage distributors as a new method of heat transfer or a new method to cool the windings. In *Davis* the main teaching is to keep the windings from failing due to voltage dielectric breakdown. The is no conflict between the Applicant's claimed invention and *Davis* in the application to motors. The Applicant's claimed invention is a completely different application directed at cooling the motor windings and the

laminations through heat removal by conduction and convection with the use of a carbon material.

Davis is not concerned with thermal conductivity of the windings or the ferromagnetic laminations to the operating temperature of the working device, this is a major structural and theoretical difference between *Davis* and the Applicant's claimed invention. The Applicant's claimed invention having as its primary goal the increase of power density by reducing the thermal resistance of the coil windings and motor laminations. At no time in *Davis* is the thermal conductivity of the materials described or the reduction of the devices operating temperature. *Davis*, indeed, tends to teach away from the Applicant's claimed device.

The Examiner, on page 4, paragraph 3, refers to *Davis* as placing one or more non-metallic (Column 2, lines 23-31), flat, thermally conductive strips, for the purpose of improving thermal conductivity in coils. The Applicant respectfully submits that the Examiner erred in the determination of the purpose of these elements. This reference would more properly be placed in a discussion of *Glass* in the following section.

In the magnetic core patent of *Davis*, there is no teaching as to the reduction of mass or size of the magnetic's due to and increase in current density or a reduction ov operating temperature, *Davis*, however does teach the reduction of mass due

to the interleaving of non-magnetic material between the laminations while maintaining a valid magnetic circuit, thereby lowering the weight of the circuit.

Therefor, I respectfully request that the Examiner's rejection No. 3 be dropped and the Applicants claimed invention be issued.

6. *Glass* is mainly teaches the application of magnets to the neck of a cathode ray tube used in television sets to focus the electron beam on the face of a TV screen. In addition, *Glass* also suggests that the invention could be applied to motors to reduce the total weight by adding addition air gaps between the laminations.

One of the main teachings of *Glass* is to reduce the quantity of the magnetics material used in each application. A non-magnetic material is interleaved into and between the ferromagnetic laminations and is said to be a non-magnetic sheet with fibers or the like of, type of material is not taught in *Glass*, with no comment as to the thermal conductivity or the need to reduce the thermal resistance of the magnetic assembly.

Glass has no teaching as to the application of thermally conductive cooling strips to improve the operations of the magnetic structure. Similarly, it is respectfully submitted that the use of non-metallic, flat, thermally conductive disks for the

purpose of improving the cooling performance of the stator structure, as cited by the Examiner on page 5, paragraph 4, is incorrect. Applicant upon review of the *Glass* patent cannot find any evidence to confirm the Examiner's basis of rejection.

Further, there is no showing of any teaching that would motivate a person skilled in the art to combine the teachings of *Herron; Glass*, *Kanai* and *Jarczynski* to duplicate the Applicant's claimed invention.

7. *Jarczynski* teadches the utilization of cooling passages designed into the outer motor casing where chilled water could be pumped through to remove heat from radial non-magnetic thermal conductance paths. *Jarczynski* provides preferential solid paths of thermally conductive laminations made of non-magnetic thermal conductor said to be copper. *Jarczynski* teaches the use of non-magnetic thermal conductors, such as copper which is a metal and a good conductor of electricity and therefore subjected to eddy currents when placed in a changing magnetic field as one would find within the motor laminations. In addition, copper has a positive temperature coefficient and its resistivity increases with temperature rise due to an increase in Rho, ρ. *Jarczynski* brings to light that these non-magnetic laminations made of copper will be subjected to eddy currents and cause additional heating,

The *Jarczynski* patent requires additional overhead for this

technical approach to be completely effective and not shown on such patent. The inventor fails to discuss that most of the heat losses in the generator windings is from the I^2R power losses in the generator/motor windings and not the power losses in the motor laminations. The preferential thermally conductive laminations made of copper are placed in direct contact with the high density, high frequency magnetic fields. Power losses from eddy-current losses, in the form of heat are ~70X more because copper is a better conductor of electricity than high modulus carbon fiber in the same magnetic fields. This is a material difference between the Applicant's claimed invention and *Jarcynski*.

The Applicant's claimed invention provides a unique thermal interface solution that is superior to *Jarczynski* and is not technically flawed due to excessive eddy-current losses in the materials and adding to the motor heat load. By using a high modulus carbon fiber a direct thermal path is provided from the interior of the motor windings to the outside motor casing, thereby providing a cooling path to the windings directly. This minimizes the migration of heat into the motor laminations, allows for an increase in current density, reduces total system weight, reduces volume and improves system reliability. *Jarczynski* merely conducts the heat off the outside of the windings unlike the high modulus carbon thermal interface which

goes directly into the interior of the motor windings. This is the critical difference between the prior art and the Applicant's claimed invention because none of this prior art withdraws heat directly from the interior of the motor windings thereby allowing the motors to run more efficiently because the motor windings will remain cooler due to the direct thermal path to te ambient atmosphere provided by the high modulus carbon thermal conductor where the interior heat is dissipated through either radiation or forced air.

When the Applicants claimed invention is applied to motors, they will run more efficiently because the motor windings remain cooler due to the direct thermal path to the ambient atmosphere provided by the K1100 material where the heat can be dissipated through forced air methods, making the system weight much lighter for airborne applications. High modulus carbon fiber known as K1100 material conducts heat a ~2.4X better than copper with ~70X less eddy current. The benefits of the Applicants claimed invention thermal interface are very important to future motor development and different enough to merit a patent in my opinion.

8. As the person signing below:

I declare that all statements made herein of my own knowledge are true and that all statements made on

information and belief are believed to be true; and further hat these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the patent application or any patent issued thereon.

Date: 26-JAN-01

Gregory A. Cowart